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TROPICAL CRITICAL REGIONALISM: CLIMATE RESPONSE PLANNING FOR BONNY ISLAND BUILT ENVIRONMENT

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ABSTRACT

Tropical critical regionalism describes a focus on the local and the specific to a tropical region or to a unique, distinct tropical area occupied homogeneously by things having common characteristics or influenced by a common phenomenon, usually the climate. The phrase applies to Bonny Island whose geographical location bestows unique and distinct climatic challenges. Standout data, for instance, reveals that Bonny Island receives approximately 4000mm of rainfall and average relative humidity of 86% annually, amongst the highest of any Nigerian town. Also, painfully obvious is the fact that predominantly, as with most parts of the country the Bonny Island built environment is not climate smart, consisting mostly of housing with extremely poor ventilation and hardly any open spaces, lacking both good sanitation and effective drainage facilities and paying little or no heed to issues of climate and the environment. Compounding the issue are both global warming that is likely to increase weather extremes and the expected population explosion due to the geometrically expanding employment opportunities of Nigeria Liquefied Natural Gas Company (NLNG ***SevenPlus***). In addition, the road link to the mainland and its consequent potential for migration into the island, all underscore the importance for researched guidelines on critical climate response planning. The paper established the inadequacies of the broad regional approach to climate response for design purposes, opting for critical regionalism, using site-specific climate variations as determinants of design parameters and guidelines. Analysis of climate data identified persistently high rainfall, temperature, and humidity as the key climatic elements militating against comfort and sustainability of the Island's built environment. Data analysis guided by considerations for critical climate response planning, determined the conclusions and recommendations for the Island's built environment. A simulation of the proposed built environment incorporating the proposed guidelines for climate mitigation expanded the potential for both specialists and laypersons to understand readily the ideas that govern the critical climate response planning, and thus help stakeholders participate in people-centred decision-making during the design process of the Bonny Island built environment.

1.0 Introduction: Tropical Critical Regionalism.

The concept of critical regionalism, which entered the architectural debate in the early 1980s, is an approach to architecture and physical planning that advocates for the design of built environments to respond to the needs and opportunities of a specific geographical area (Tzonis, Lafaivre, & Stagno, 2001). The argument for different buildings for different climates, which advocates critical regionalism, is a strong counter point to globalism in architecture, which promotes universal values and norms. Regionalism stands for the local and the specific to a region or to a unique, distinct geographical area occupied homogeneously by things having common characteristics or influenced by a common phenomenon, usually the climate.

Climate responsive architecture has been a topic of interest throughout history. In their book *Design with Climate, Bioclimatic Approach to Architectural Regionalism,* Olgyay & Olgyay, (1963) identified a remarkable congruence between special architectural features and certain climatic zones. They referred to leaders of thought from the classical Greek philosopher Socrates to the renowned French Architect Le Corbusier, on the parallel observation of the relationship between climate, and the built environment and #the need for differences in design responses from different zones. They cited the writings of first century Roman Architect Vitruvius in De Architectura saying.

> **"For the style of buildings ought manifestly to be different in Egypt and Spain, in Pontus (Turkey) and Rome, and in countries and regions of various characters. For in one part the earth is oppressed by the sun in its course; in another part the earth is far removed from it; in yet another it is affected by it at a moderate distance".** (Vitruvius, 1931).

Similarly, in their book Tropical Architecture in Dry and Humid Zones, Fry & Drew, (1982) proposed that: The three main considerations influencing architectural design in the tropics, which distinguishes it as belonging to the zone, are:

- People and their needs
- Climate and its attendant ills
- Materials and the means of building

They opined that the concerns where intricately related and had evolved into built environments with distinct physical characteristics (Fry & Drew, 1982).

Imaah (2008) identifies the nurturing role of biomimicry in solving problems of the built environment, asserting that the successful built environment and the natural environment intertwine inseparably in an intricate symbiotic relationship. He further established that the climate is fundamental to the forms of architecture that propagate.

Author/Artist Miles Dandy referred to the integration of social and cultural needs and building forms and materials with the tropical climate concerns as the "grammar of architectural design" for the tropics (Danby, 1963).

Another argument for critical regionalism has Lawal (2013) calling for climate responsive built environments, noting that the effect of adverse climate could be reduced with climate responsive parameters. In this way, the built environment created in response to the prevailing climate, modifies and isolate the interior environment from temperature and humidity fluctuations provide shelter from prevailing strong winds and precipitation and feature enhancements that allow for natural light and fresh air.

Bonny Island falls within the tropical region defined by the geographical area between the tropics of Cancer ($23^0 26^'$ N) and Capricorn ($23^0 26^'$ S). This region, which is hardly homogeneous, stretches all around the earth from the pacific Islands, Southeast Asia and Australia to India, Africa, the Caribbean and portions of the Americas. The region is vast, and geographers view the "tropics" more as a family of tropical regions lying between and near the boundaries of the parallels. This region, which is as varied culturally as it is geographically, has certain common climatic, political, and historical facts that affect the built environment. They include:

- The dominant climatic influences that affect building sustainability and human comfort are heat, humidity and rainfall, which prompted Yew (2000) Singapore's standout prime minister to state of the region, “High productivity is difficult to achieve.”

- The traditional ways, which were at peace with the environment, have changed because of the indiscriminate influx of conflicting foreign cultures, religions, technologies, and architectural styles, Imaah (2008).
- The political and historical fact that all this region being ex-colonies, struggle with the common need to overcome the post-colonial frame of mind that inhibits fresh and independent points of view (Tzonis *et al*., 2001).
- There is the common existing heritage from the colonial era, of building types and urban fabric into which the post-colonial architecture and physical plan is forced (Tzonis *et al*., 2001).

Roaf, Fuentes, and Thomas-Rees (2003); Imaah (2008); Imaah (2010) view the built environment as part of a complex interaction between people, climate, and the natural environment. Just as man affects the environment, the natural environment has a strong influence on the thinking and way of life of human beings. Human beings and the environment influence each other intricately, which feeds into the concept of Environmental Determinism, which advocates for the impact of environments on the actions and character of people and collectively their societies. The underlying assumption is that human beings are infinitely adaptable, and that they will respond in the way that architects and planners deem desirable and that they will give up without reaction, any tendency to reshape their built environments. That this view was debunked by the Pruitt Igoe housing project debacle in St. Louis, Missouri U.S.A. in the 1950s and effectively replaced by the concept of Socially Responsive Architecture, advancing the case for critical regionalism, which implies different buildings for different situations, is note worthy (Tzonis *et al.,* 2001). Pleasant built environments that ensure physiological comfort as well as building sustainability derives from an understanding of climate and environment (Olotuah, 2001).

Buildings as designed and used today in Nigeria are not climate responsive (Ajibola, 2001). The occupants of the spaces do not enjoy thermal and visual comfort because the buildings lack spatial organization for adequate cross ventilation and consequently, need more active energy (Akinbami, 2002). Barbour, Oguntoyinbo, Onyemelukwe, and Nwafor, (1982) buttress the opinion, recognizing the structural duality of areas retaining the enclave concept of colonial urbanism that features relatively small Government Reserved Area (GRA) alongside "the rest" with poor ventilation and hardly any open spaces, lacking both good sanitary conditions and effective drainage facilities.

Bonny Island is a part of this picture. Mitigating solutions, however, starts with an appreciation of the reasons for the deplorable situation. Barbour, *et al.*,(1982) opines that as the urban population continues to rise, widening the gap between effective demand for, and supply of urban housing, the temptation to offer and the pressure to accept sub-standard housing grows inexorably.

There is a consensus by researchers on the importance of climate responsive built environments, which supports the narrative of tropical critical regionalism. However, the complex process of evaluating human comfort conditions takes into consideration various environmental and physiological factors all acting stochastically within a range of values.

Olgyay (1962) proposed the bioclimatic chart that relied on a temperature-humidity relationship for analysis of comfort conditions within the comfort zone, but outdoor climate conditions were the basis of the physiological analysis resulting in its limited applicability indoors. Givoni, (1976) used the psychrometric chart to define the comfort zone and the limited range of outdoor climatic conditions in which certain passive control strategies could still deliver indoor comfort. Szokolay (1986) modified the psychrometric chart, defining the "Control Potential Zone" (CPZ) as the range of outdoor atmospheric conditions within which indoor comfort could still be achieved by passive design strategies. Lawal (2013), researched physiological comfort in South-West Nigeria using Control Potential Zone (CPZ) of psychrometric charts since broad climate classifications were not particularly useful for building design. He concluded that:

- Climate variations based on a specific site's location in South-Western Nigeria should influence the design guidelines and principles of built environments.
- There is the need to continually carry out climatic observations and location specific data collection of parameters that may affect reaction of building envelopes to weather variables.
- The updates of these data should form the basis of design conceptualization of the openings and spatial distribution to ensure attainment of a comfortable internal environment.

As valuable as these intellectual research outcomes are, they hardly offer specifics on how to create the overall built environment that is adequately climate responsive. Post-colonial era-built environments seem cognitively tied to the global view of the colonial masters. This paper, relying on the analysis of the detailed archival climate data, and recent survey responses, individual depth interviews and direct observation, aims to explore and generate climate responsive parameters and guidelines for Bonny Island that are critically regional (though not necessarily opposed to positive global potentials) but devoid of the corrupting influences of the colonial era mind-set.

2.0 Bonny Island Climate Summary.

A summary of the characteristics of the Bonny Island climate as revealed by the detailed climate data obtained from Weather Spark is as follows:

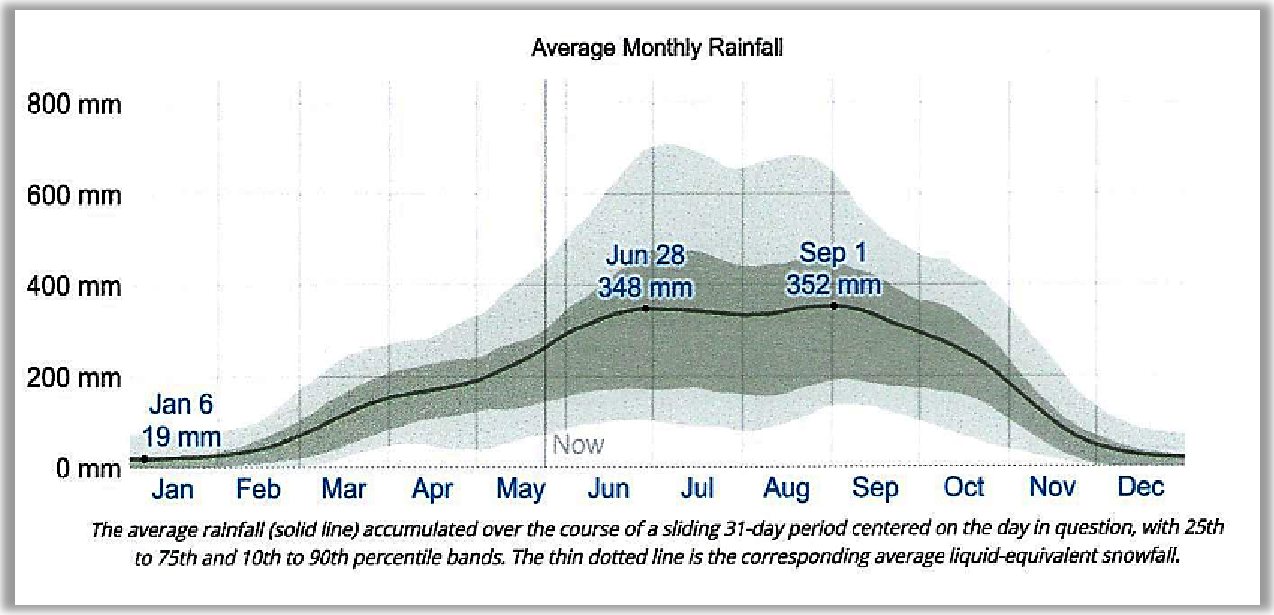


Figure 1. Average monthly rainfall. (Source: Weather Spark).

Rainfall.

The climate of Bonny Island is classified "Af", tropical rainforest (Koppen-Geiger climate classification; 1980-2016) Figure1.3, with two distinct seasons. The wet season is warm and overcast (7.8 months, March-November) with double maxima peaking in June and September while the dry season is hot and mostly cloudy (4.2 Months, November-March). Rainfall is significant, with precipitation even in the driest month. The average annual rainfall is 3822mm of rain. January is driest month while September is wettest.

Temperature.

The sun rises in the east and maintains a predictable path across the sky to set in the west. The predictable range of solar positions, which is useful for a variety of design options, is a function of the season, the month and time of day. The weather is muggy (humid) and oppressive with temperature variation from 21°C to 31°C, and annual average temperature of

26.7°C. March is warmest with average temperature of 28°C while August is coolest with average temperature of 25.4°C. A difference of 2.6°C.

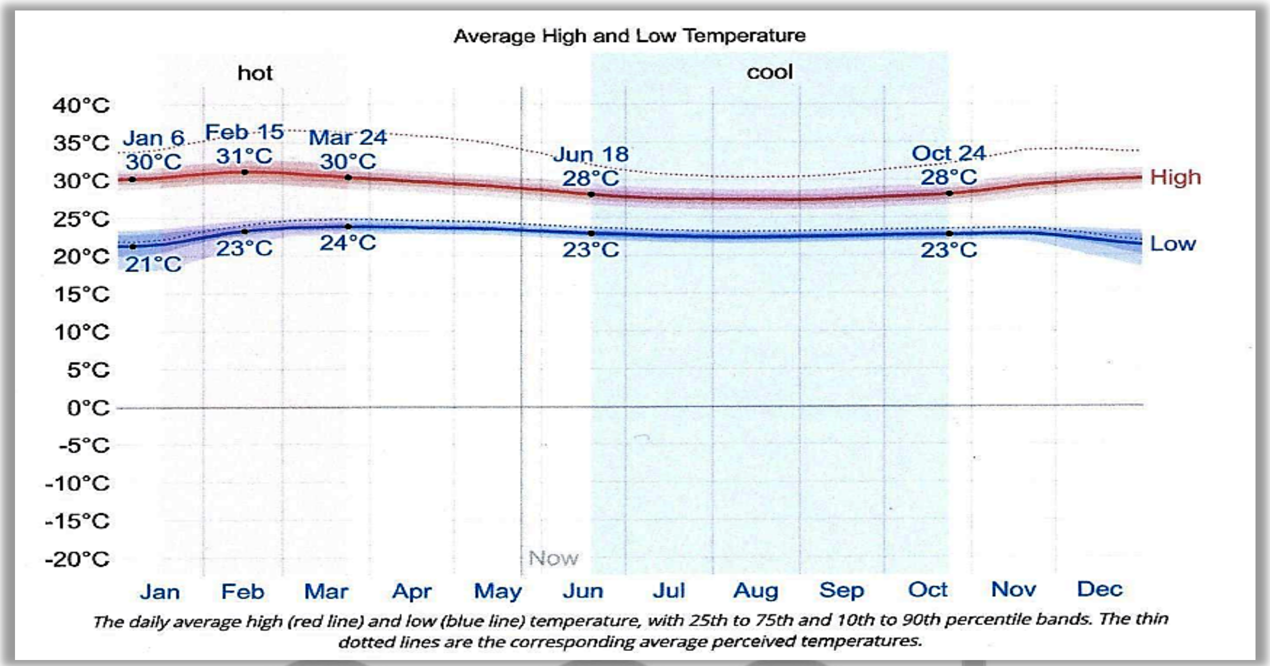


Figure 2. Average high and low temperatures (Source: Weather Spark).

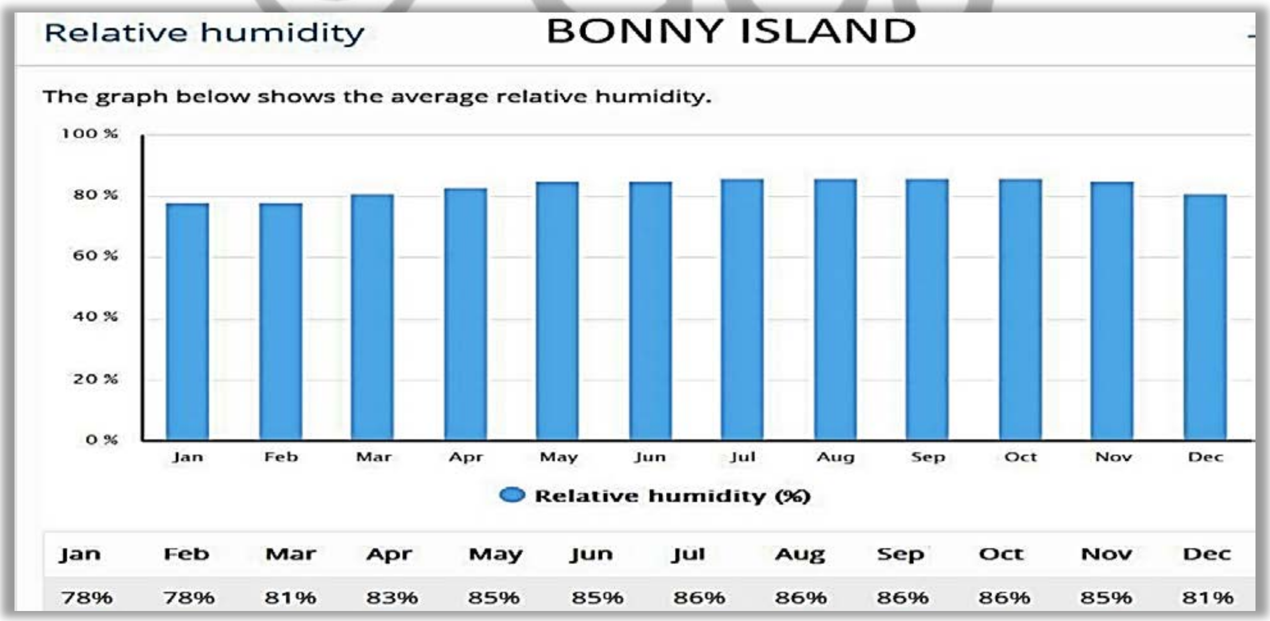


Figure 3. Average Monthly Relative Humidity for Bonny, Nigeria.
(Source: https://www.weather2visit.com).

Humidity.

Relative humidity is high, 86% on the average for 11 months (January28 – December28) during which time, the comfort level is muggy, oppressive, or miserable at least 90% of the time. Yearly average is 83.3% RH.

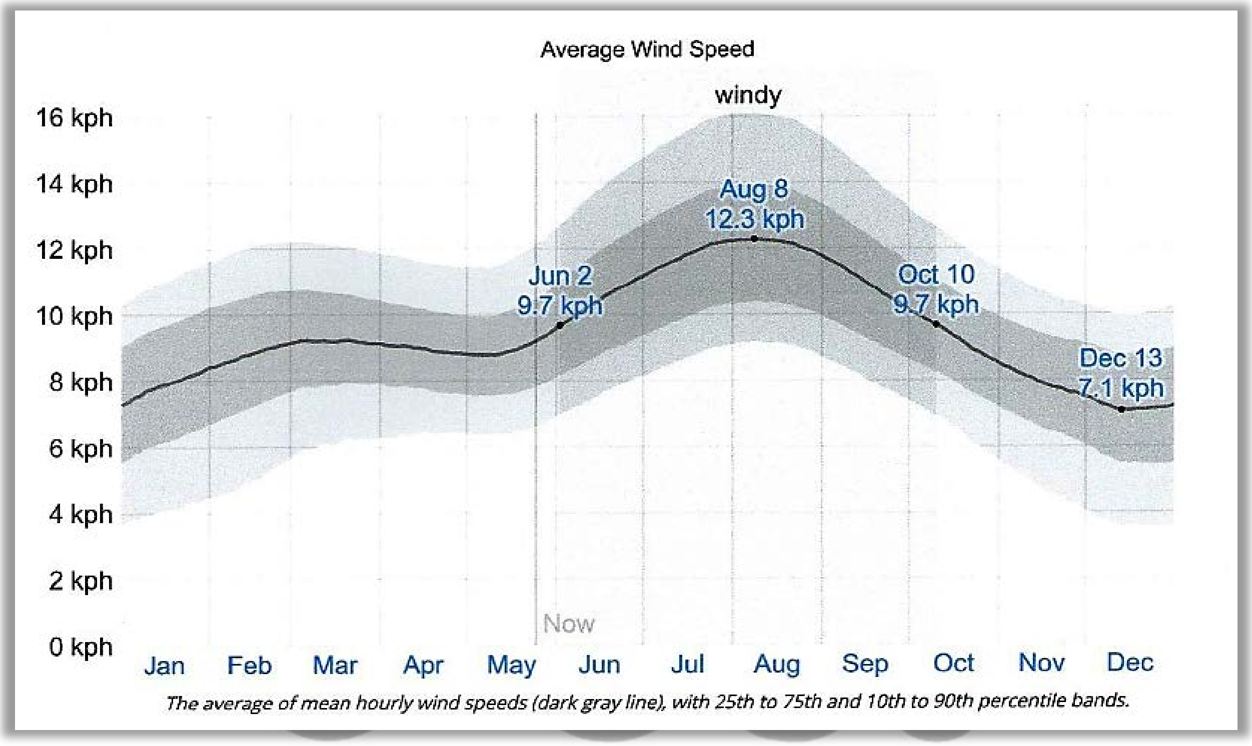


Figure 4. Average Wind Speed Bonny Island (Source: Weather Spark).

Wind Vector.

Wind direction is mostly from the southwest. The windiest time of year lasts from June to October with average speed of 12.3 kph. The rest of the year from October to June is calm with average wind speed of 7.1 kph.

The stochastic interaction of the various climatic elements constitutes the weather and thus the climate. Extracting from the analysis of the detailed archival climate data, survey responses, individual depth interviews and direct observation, the standout climatic elements that constitute challenges to the architecture and physical plan of Bonny Island are precipitation, humidity, and temperature. The combined effect of these elements affects thermal comfort and sustainability of the built environment. An understanding of their various effects results in designs of built environments that are climate modifiers, filtering out adverse climatic effects. The Table 1. below shows the problematic effect of the various combination of humidity and temperature.

Table 1. Effects of the Various Combination of Humidity and Temperature.

CONDITION	EFFECT	SOLUTION
HIGH TEMPERATURE & HIGH HUMIDITY.	SWEATING DISCOMFORT IF PERSPIRATION IS NOT EVAPORATED	AIR MOVEMENT ACROSS THE SKIN
HIGH TEMPERATURE & LOW HUMIDITY.	DRY AIR; FASTER LOSS OF MOISTURE FROM SKIN. (DEHYDRATION).	COOL SHADE/AIR MOVEMENT & REHYDRATION
LOW TEMPERATURE & HIGH HUMIDITY.	CONDENSATION ON COOL BUILDING SURFACES. MAY CAUSE DETERIORATION OF MATERIALS.	AIR MOVEMENT ACROSS BUILDING SURFACES

(Source: Darji, 1974).

On Bonny Island, a current of air across the skin or through the built environment offers some level of relief thus strategies to reduce heat gain, encourage heat loss and dissipate humidity are appropriate response options for high humidity and temperature.

3.0 Climate Analysis and Response Strategies.

The climate of Bonny Island is humid, warm, and wet, a climatic problem that makes high productivity difficult to achieve, (Yew, 2000). Compounding the problem, the detailed climate data, surveys, in-depth interviews, and direct observation all reveal that the Bonny Island built environment does not respond appropriately to its own climate. Climate response objectives, of the Bonny Island built environment derive from the dual focus on user comfort and building sustainability. American National Standard (1966), defines comfort as "that condition of mind which expresses satisfaction with the thermal environment". The comfort zone is also the range of climatic conditions within which most people would not feel discomfort either of heat or cold". It corresponds to a range of 20ºC - 30ºC dry bulb temperature with 30% - 60% relative humidity (Darji, 1974). The Bonny Island climate does not fit comfortably in the comfort zone thus, would benefit from climate response strategies that focus on the following objectives:

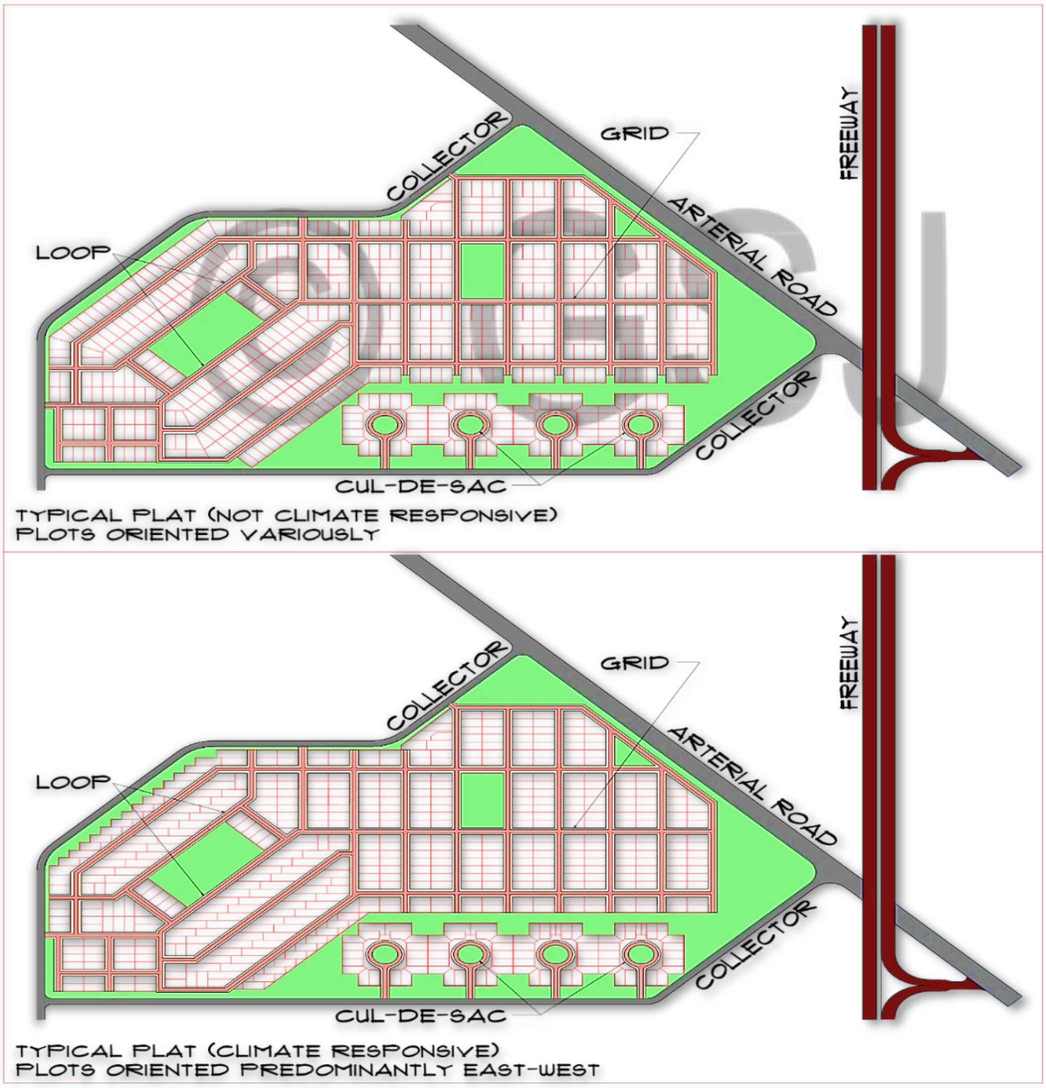
- To passively minimize heat-gain and promote heat-loss.
- To passively dissipate humidity.
- To mitigate the consequences of rainwater inundation.
- To harness the drying/hygienic benefits of the sun for outdoor spaces.

Achieving the above objectives for the Bonny Island built environment would require the generation and application of design strategies starting from the considerably basic neighborhood layout planning, plot spacing and orientation, to the building's orientation, form and overall design. Darji, (1974), Evans, (1989) and Ogunsote & Prucnal-Ogunsote, (2002) opine that the three levels of defense in the bid to passively achieve the climate smart built environment are:

- Landscaping and Vegetation
- The Building Fabric
- Passive Technologies (Strategies)

3.1 Street/Plat Layout, Landscaping & Vegetation.

Plots can be of various sizes but for ease of understanding I assume the conventional, generally accepted modular size of 15m x 30m ($450m^2$), which may be increased as necessary along modular dimensions. Of greater significance to climate response is the plot and street orientation, which where possible should be oriented in the East-West direction. Along with all other considerations for determining the plat layout, serious attention should be given to the site planning, particularly the street/plot orientation. The illustration, Figure 5 shows how the plot orientation if given due consideration, can be oriented in the east west direction which lends itself much more readily to climate responsive designs of the Bonny



Island built

Figure 5 Contrasting Climate Responsive & Unresponsive Plat.
(Source: Generated by Researcher).

environment. Based on the solar path and predominant wind direction, this orientation readily lends itself to the ideal East-West building orientation most suited for minimizing building heat gain and encouraging ventilation on Bonny Island.

The 15m x 30m plot oriented East-West constrains the eventual building design of the conventional (independent) single-family residential unit to the East-West orientation. Modular increases in plot size where necessary should try to retain the configuration that, if squared at corners as much as possible would allow the elongation of buildings in the East-West direction with adequate space all around, preventing buildings from shading each other. Thereby taking full advantage of the drying and hygienic benefits of the infrequent sunshine. The simultaneous enforcement of the existing (3-meter) building setback restrictions for mid-density areas in urban Bonny Island is instructive. It maintains a minimum distance of six meters between buildings so, with a 45° solar angle (approximately between 9.00am and 3.00pm) and building height of six meters no building is in the shadow of another. A skewed plot configuration presents greater challenges to the efficient use of the plot in terms of building placement.

Unnecessarily wide streets reduce potential landscaping area and increase the ground area sealed off to water penetration, which aggravates flash floods or temporary flooding. They add to the area that reflects insolation, which increases urban heat and can deceptively encourage over speeding in speed-restricted zones.

Landscaping and vegetation are effective tools for responding to the prevailing climate as it has the potential for climate moderation. The careful selection of ground covers, plants, pavement materials, etc. determine the amount of solar radiation absorbed or reflected. Ogunsote & Prucnal-Ogunsote, (2002) define the 'almond tree effect' as the modification of microclimates produced by trees (Figure 6b). The almond tree has layers of horizontal branches all the way to the treetop, with broad leaves that offer filtered shade. The upper leaves receive most of the heat while the lower leaves receive less heat and are thus much cooler resulting in cooler air flow around the base of the tree which can be channeled to the building. Even in the absence of prevailing breezes, the temperature differential between the top and bottom branches generates a convection current, which keeps cool breezes swirling around the base of the tree. This type of shading with trees is more effective on the western side of the building where it helps to protect the building from low angle (western) solar rays. Landscaping and vegetation also respond to the climate in other ways. Evapotranspiration, where plants take water from the soil and release to the atmosphere by evaporation through the leaves, is a cooling process as the latent heat of evaporation comes from the surrounding air. This also has the advantage of removing some moisture from the soil thus preparing the soil for sponge action by the next rainfall (DAS, 2008). Evapotranspiration also works with wall creepers and climbers, taking moisture from the support surfaces and releasing to the atmosphere with the resultant cooling and added advantage of protecting the wall surface from direct insolation. Plants can also be used as windbreakers or wind channels, blocking, or reducing air velocity and wind speed or channeling the air in some desired direction that is to the advantage of the built environment.

3.2 The Building Fabric.

In the effort to achieve thermal comfort, analysis of information gleaned from the solar path diagrams for Bonny Island from summer solstice to winter solstice, suggest an East-West building orientation to minimize heat gain. This is because to minimize heat gain one must minimize solar penetration. As the sun rises in the East and sets in the West, (before 9:00am and after 3:00pm), the solar angles are too low for any practical horizontal shading devices to be effective in preventing solar penetration directly through openings and glazing. To minimize heat gain, it is therefore prudent to present the building's smallest dimensions to the East and West thereby reducing potential for solar penetration from the east and west where horizontal shading is ineffective. As the sun continues along its path (approximately from

9:00am – 3:00pm), it spends considerable time overhead beaming down harshly on tropical environments. Thus, the East-West building orientation strategy for minimizing heat gain simultaneously requires a roof system that acts as a near perfect insulator, completely protecting the building from overhead solar radiation. As the sun continues along its path to set in the West, the built environment, which in addition to the cumulative indirect heat gain for approximately nine daylight hours, would now be receiving low angle solar radiation from the West. Consequently, the building's thermal mass is considerably warmer in the evenings as the sun, sets. This suggests shading strategies preferably with carefully selected vegetation on the western side of the built environment that blocks the low angle western sun and provide cooling shade to West side of the building, (The almond tree effect)..

Further analysis of the solar path reveals a need for shading from higher angle sunlight on both the South and the North sides of the building at certain times of the year. The latitude of Bonny Island (4.42°N), just North of the Equator means that the sun spends more time beaming down on the Island from the South than from the North. The altitude of the sun at noon during the solstice is appropriate for the design of horizontal shading devices. The values are 61.17° due S for the winter solstice and 69.91°due N for the summer solstice. These angles are necessary to determine the extension of shading devices like roof eaves or horizontal window hoods. Roof extension (eaves) over the perimeter wall (south side) of a 3m high bungalow can be determined graphically to be 1.2m and 1.5m respectively, (Figure 6c).

Climate response strategies for minimizing heat gain, complemented by passive cooling, using natural air movements by design is ideal. Movement of air across skin which causes cooling due to evaporation of perspiration relies on natural air movement in two ways. In the first, air movement is due to a pressure differential from the positive pressure to a negative pressure zone. The rate of flow is proportional to the magnitude of the obstruction causing the pressure difference, Evans (1989). In other words, the pull of air through and around the building is proportional to the size of the building obstructing the airflow. The second air movement relies on convection currents where warm air rises and is replaced by cooler air. Here the rate of airflow is proportional to the difference in the level of the openings thus, greater airflow is induced by greater difference in the level of the openings, (Fathy, 1986).

The epic aphorism, ***"We shape buildings; thereafter they shape us,"*** Churchill, (1943) is an eloquent expression of the architectural longevity phenomenon, illuminating the fact that the built environment is a static artefact that continues to impact people long after the completion of its construction. An error in the implementation of user comfort parameters becomes a permanent imposition of discomfort on eventual users. Given the stochastic nature of the climate, and in consideration of passive design strategies for climate response, only apertures for ventilation with size variable windows have the flexibility to passively respond to the variations of the weather in order to enhance comfort.

On the warm wet humid Bonny Island, passive cooling through ventilation would require the application of both ways of inducing air movements through the building's open doors and low windows, letting the air through the lower part of the house where people are while simultaneously flowing acrossing as many building surfaces as possible in order to take away as much heat as possible on its way to exit the building, that is, a combination of people cooling and building cooling strategies. Building design strategies to harness the cooling potential of air movements start with identifying the most appropriate building orientation with regards to the prevailing wind direction. The predominant wind direction on Bonny Island is from the South-West direction and it would seem that a rectangular building oriented North West – South East, having its longer dimension blocking the path of the wind wuold be ideal. This orientation, however, is at odds with the orientation suitable for minimizing solar heat gain discussed earlier. Rotating back to the East-West orientation not only conforms to the requirements for minimizing solar heat gain, but interestingly blocks the path of the wind with its longest dimension (the building diagonal) thereby, generating the greatest pressure differential and thus strongest pull of air through the building (Figure 6a). Complementing this air movement with convection induced airflow requires low windows and high clearstory, size variable windows in a bungalow, but would be more effective in a storey building with a double volume living room space where there is a greater distance between the lower and upper window openings.

Built on standards of the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 62.1-2016 section 6.4 "Natural Ventilation Procedure" Building Codes specify that the minimum openable area to the outdoors (windows) shall be at least 4% of the floor area being ventilated. Where rooms and spaces without openings to the outside are ventilated through an adjoining room the unobstructed opening shall be at least 8% of the floor area of the interior room or space, (Federal Republic of Nigeria, 2006)(6.2.4.1 and 6.2.4.2). This general specification does not adequately address the extremely high humidity and rainfall of Bonny Island. Studies on attributes for best performance in natural ventilation carried out in Brazil, (Sacht & Lukiantchuki, 2017) as well as in India, Yang & Clements-Croome, (2012), reveal best results for air exchanges using window openings of 25% and 20% of floor area respectively, with wind incident at a 45º angle to the window opening. Relying on these studies and local conditions of the study area the recommendation is for window openings of at least 20% of relevant floor area with a building orientation that presents the windows at a 45º angle to the predominant wind direction. The general idea is to have maximum feasible net airflow through the spaces, restrictable to "comfort" with size variable, operable windows that offer control on the precise amount of airflow through the space. The airflow desipates the humidity, the real cause of the perception of higher than measured temperatures due to little or no evaporation.

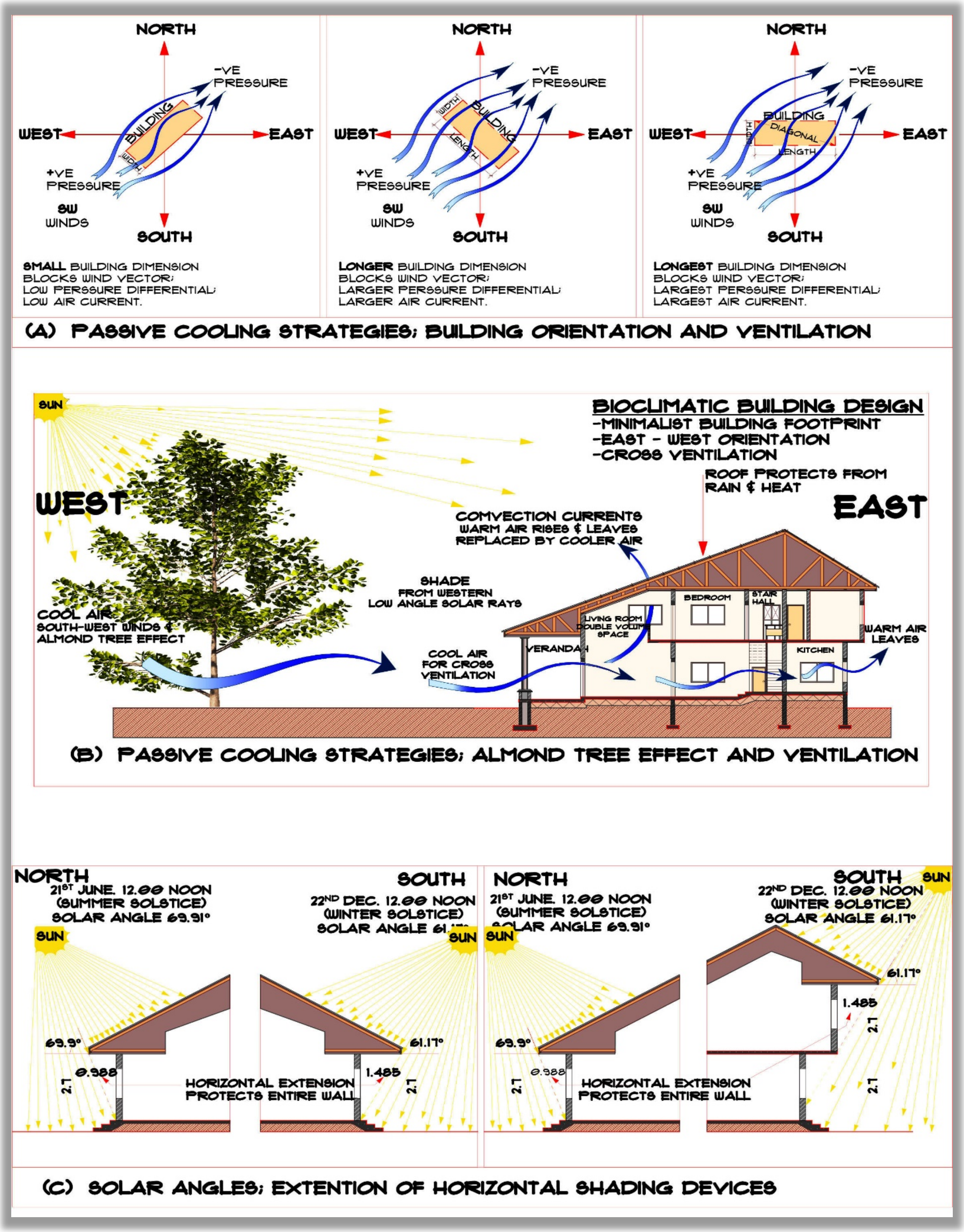


Figure 6. Passive Cooling Strategies (Source: Generated by Researcher**)**

4.0 Recommended Critical Climate Response Guidelines for Bonny Island.

Based on analysis of the Bonny Island climate, and guided by considerations of appropriate climate response, mitigating recommendations are as follows:

1) Generally, the recommendation is for a holistic approach to property development of larger plats of land by reputable developers rather than the unitary approach in which every individual is responsible for his own property development. It multiplies climate response advantages which have urban scale impacts. For example, economies of scale apply. There is a reduction of urban heat sources, site and services is far more efficient, and the advantages of concepts for weather management dramatically increase.
2) The general plat (site/plot) layout at the neighbourhood level should as much as possible lend itself to designs with an obvious East-West orientation. This is fundamental to appropriate climatic response and underscores the importance of the holistic approach to plat developments.
3) Development of the design for the built environment should capitalise on the natural lay of the land and on drainage systems for surface water run-off away from buildings by taking the "high ground" where feasible. It increases potential for passive run-off of rainwater into surface drains after rain events.
4) Open green areas strategically interspersed within the neighbourhood plat would encourage and enhance airflow and air speed through the area. Having the potential for higher evaporative cooling, air exchanges, and the dissipation of humidity, it allows the built environment to breathe, letting airflow through rather than around.
5) The general landscaping of the area should rely on plant material as ground cover as much as possible, with minimal use of hard ground sealing cover. Where hard ground cover is necessary interlocking stones that allow for water penetration into the soil is preferable. Appropriate placement of shade trees on the west of would enhance

cooling by providing shade from the "hot" western sun and afford the built environment the advantages of evapotranspiration and the "almond three effect".

6) Compliance with statutory setback restrictions, would guarantee solar rights and the consequent hygienic benefits of the sun. For efficiency, designs should have minimal footprint for its functions, (minimalist designs).
7) Building envelope protection from rain and insolation imply steep roof slopes (30º+) with deep vented ceiling space. As much as possible, the 'open plan' of the interior space and the placement of 'size variable' windows should enhance flexibility and control of airflow. The recommendation is for equal sized inlet and outlet (openable) windows amounting to 20% of floor area of space served.
8) Horizontal solar shading devices (overhangs) should be used primarily on the north and south facades of the building where it is effective. The depth of shading devices for effective protection from direct solar penetration into the building through windows is a function of its height above the opening and the critical angles of 61.17º south side (winter solstice) and 69.9º north side (summer solstice), (Figure 6c).

5.0 Simulation of a Climate Smart Bonny Island Neighbourhood.

Simulating the proposed future built environment is considered a more effective way to present and or test research outcomes, communicate with stakeholders and obtain their contributions to design ideas that originate in the designer's mind (Morello and Piga, 2016). Simulation in architecture and urban design is the production of a computer model especially for the purpose of study. Without a virtually realistic model, it is difficult to communicate future ambiances in a scientific and shareable way making it problematic for laypersons to participate meaningfully in the design process of their own spaces. Furthermore, there is the nagging query of the acceptability of urban design outcomes when in the control of one designer or design team without the socially responsible contributions of the eventual users. i.e., the Bonny Island stakeholders. Along with climate response considerations, and other design decisions involved in the built environment it is necessary to define the framework for the simulation as follows:

i. The Masterplan

The simulation relies on the current accepted Bonny Kingdom Socio-Economic Development Masterplan, which proposes the "Bonny Green Heart City" concept for the physical development of Bonny Island. Within this framework, an undeveloped area of the island is selected as the location for simulation at the neighbourhood level.

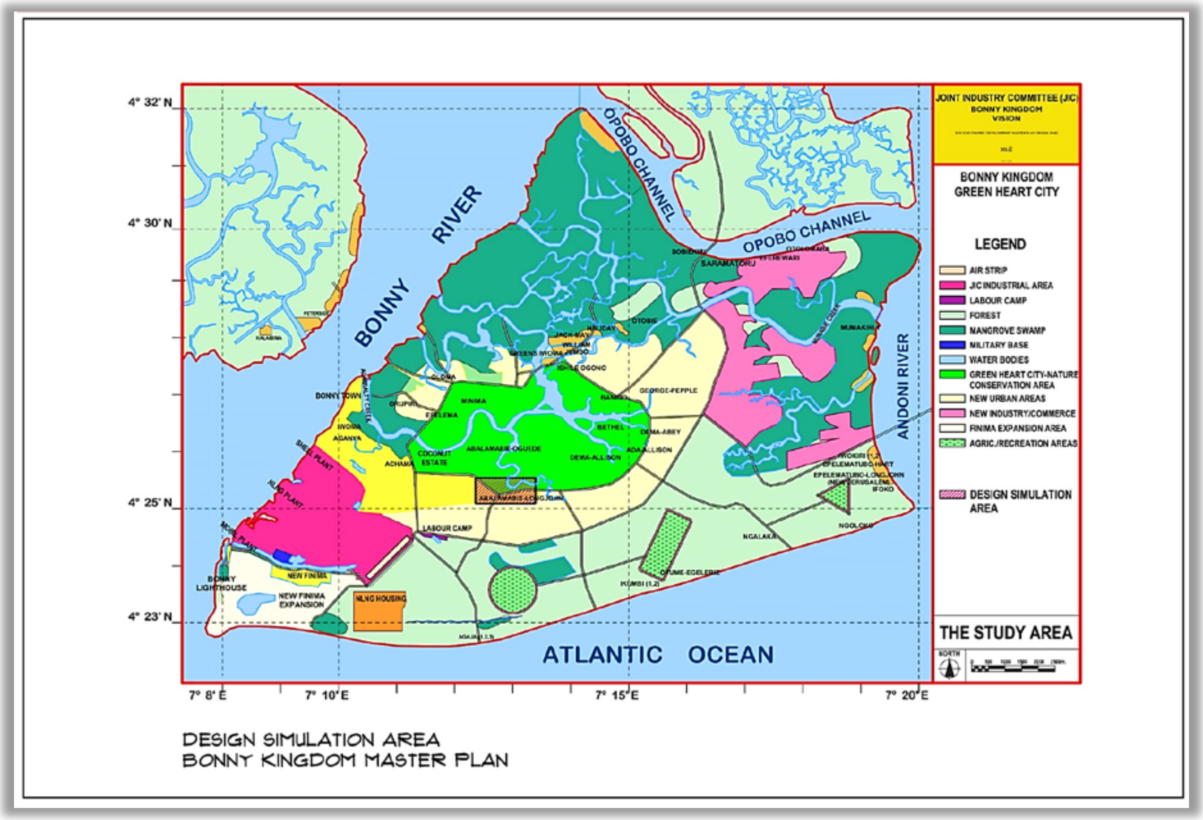
ii. River State Physical Planning and Development Law

Guided by the existing Rivers State Physical Planning and Development Law No. 6 of 2003, the simulation focuses on 2, 3 and 4-bedroom bungalows, 3, 4 and 5-bedroom single storey buildings, as well as blocks of letable units. A further consideration of the simulated option is affordability to middle-income sector of a medium density urban area.

iii. Site Analysis

The delineated area for the purpose of simulation is an area of approximately 200 hectares that includes both developed and undeveloped areas on the fringes of Abalamabie. Analysis of the site identifies the solar path, predominant wind direction and existing features of the terrain. The simulation recognizes existing roads and waterways as well as the proposed roads and flood buffer area established by the current Bonny masterplan dubbed "Green Heart City". Conclusions drawn from the analysis and design decisions for the simulation all derive from considerations for climate response objectives and relevant archival science already discussed.

Figure 7. Concept Sketch/Design by Accenture NLE



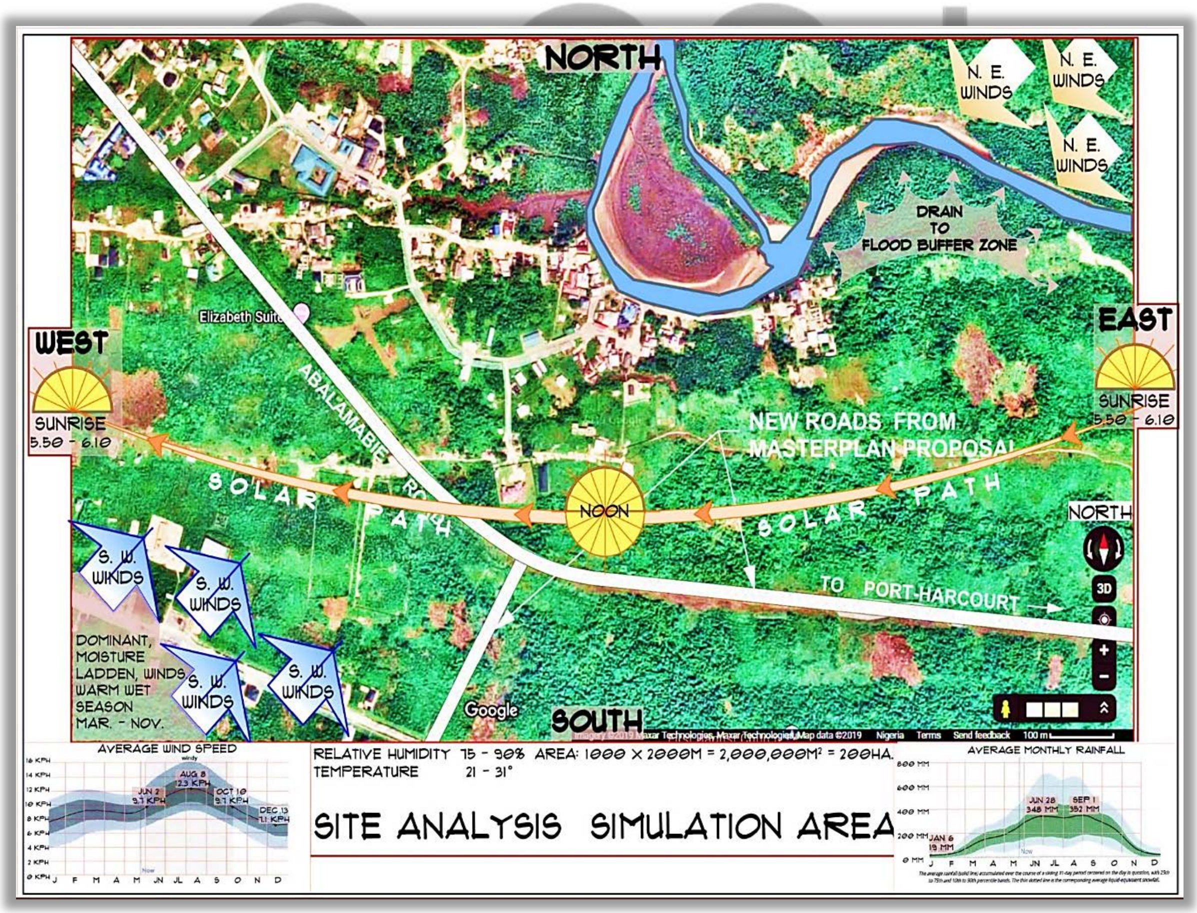


Figure 8. Design Simulation Area.
Figure 9. Site Analysis of Simulation area.

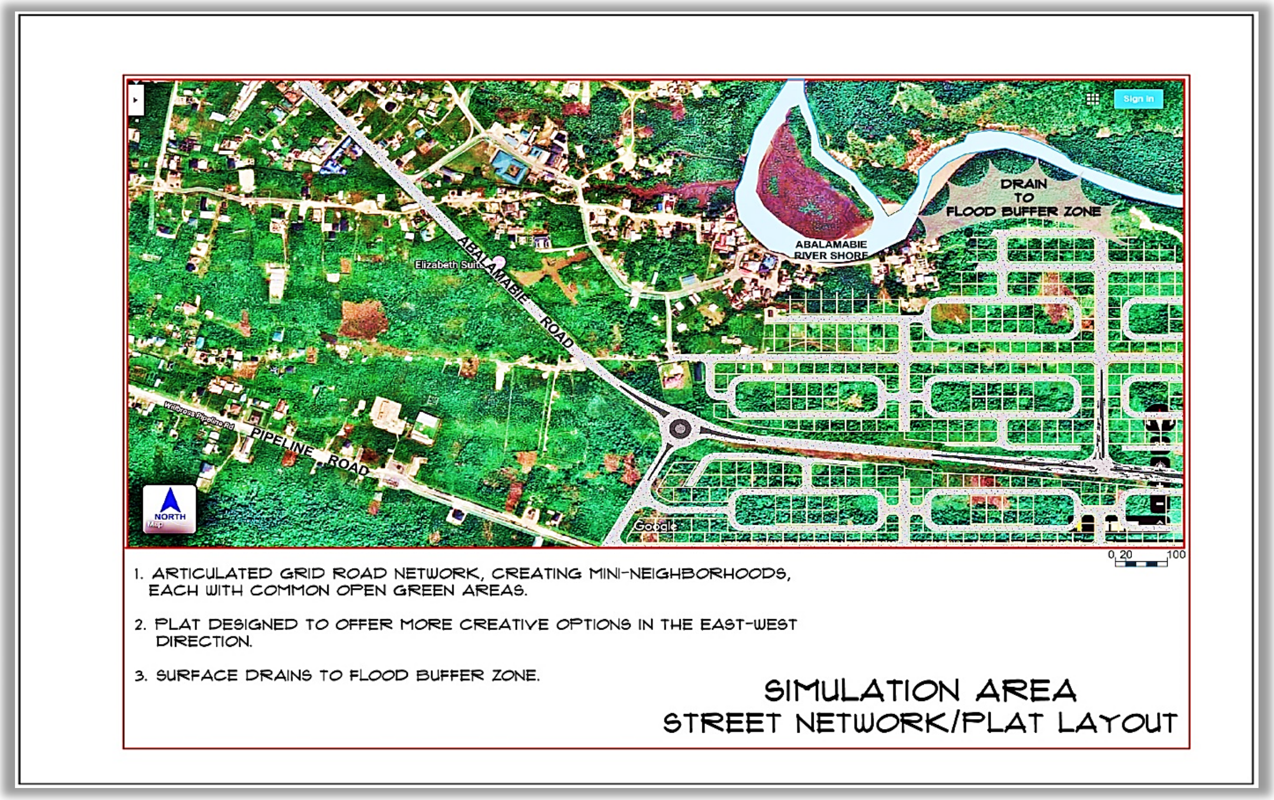


Figure 10. Articulated Grid Layout of Simulation Area.

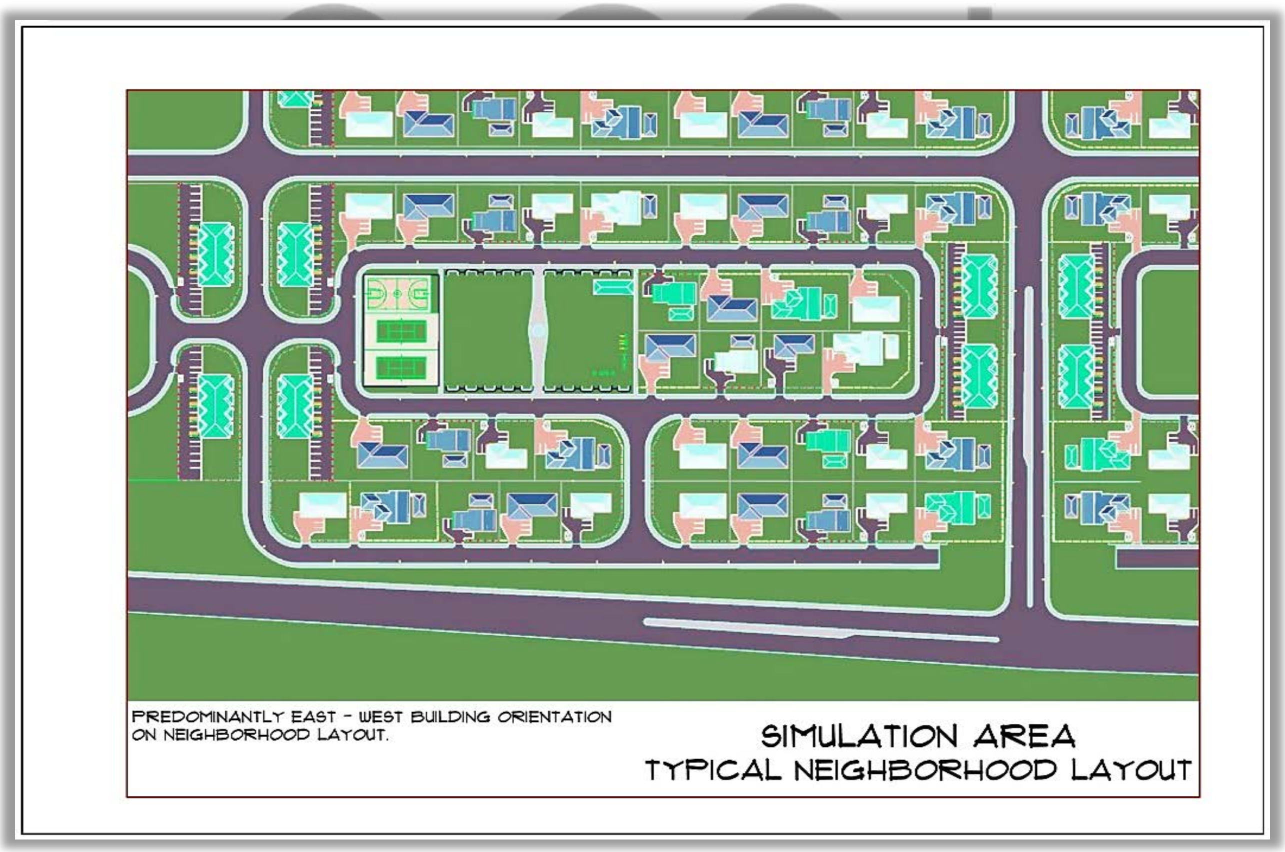


Figure 11. Typical Grid Layout.

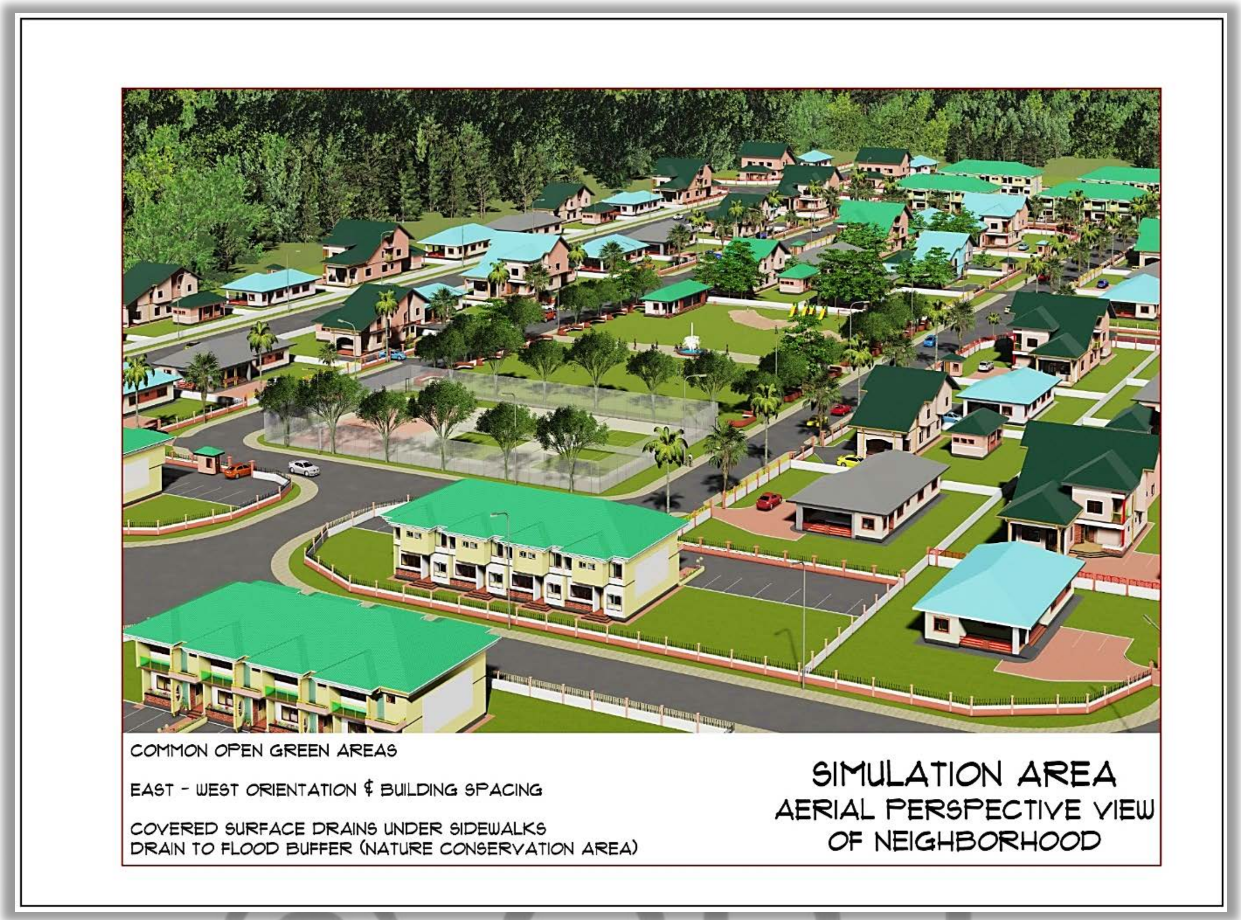


Figure 12. Aerial View of Simulation Area.

Figure 13. Aerial View of Simulation Area.

6.0 Conclusion.

The concept of critical regionalism stands for the local and the specific to a region or to a unique, distinct geographical area occupied homogeneously by things having common characteristics or influenced by a common phenomenon, usually the climate. The location of Bonny bestows the Island with a climate that poses unique challenges to the built environment. Standout data, for instance, reveals that Bonny Island receives approximately 4000mm of rainfall annually, amongst the highest of any Nigerian town. Critical climate response planning addresses the issues of adverse climatic elements specific to the insular Bonny climate and guided by both critical analysis of climate data and response considerations, propose mitigating guidelines.

A simulation of the proposed built environment effectively presents and tests the proposed guidelines, communicate with stakeholders and obtain their contributions to design ideas of the researcher. The simulation expands the potential for both specialists and laypersons to understand readily the ideas that govern the architectural and physical planning, which helps stakeholders participate in people-centred decision-making. It is expected that the simulated built environment of the study area incorporating the guidelines will continue to stimulate dialogue that would contribute to further improvements. In the final analysis, the best critically responsive option is derived from greater constructive engagement with stakeholders of Bonny Island.

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